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WATER CONTAINER LINER

R.B. Neveril, et al

General American Transportation Corporation
Niles, Illinois

September 1967

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WATER CONTAINER LINER

R. B. Neveril
A. L. Kapil

GARD Final Report 1427 September 1967

GENERAL AMERICAN RESEARCH DIVISION
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Prepared for
Office of Civil Defense
Office of the Secretary of the Army
Washington, D. C. 20310
SRI Subcontract No. 11609(6300A-200)
OCD Work Unit 1433C

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REVIEW NOTICE

This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

GENERAL AMERICAN RESEARCH DIVISION

4. Leakage through cracks in the liners resulting from embrittlement because of chemical reaction with the sodium hypochlorite bleach (Clorox) used to disinfect the water.

The present research was undertaken to overcome these problems. The effort was divided into three phases. The first phase was to identify plastic materials which were immune to attack by sodium hypochlorite and which had good heat-seal characteristics. The second phase was to investigate other designs which would eliminate the problems inherent in the "bag-type" liners. The third phase was to investigate methods for packaging sodium hypochlorite or other bleach to make it easy to add the specified amount to the water. This was considered necessary, since the rate of chemical reaction of bleach on polyethylene is proportional to the concentration of the bleach and any excess amount only accelerates deterioration of the liners.

The general conclusions that can be drawn from the research are the following:

1. If cost considerations are paramount, the present double "bag-type" liner design should be retained, but the following grades of polyethylenes which have superior chemical resistance and heat-seal characteristics should be used:

   Ethyl Company - Visqueen L

   Union Carbide Corp. - Zendel HD

   A double liner using these new materials will cost about $0.50 in production quantities.

2. For a liner significantly more reliable than the "bag-type", a blow molded, stackable design is recommended. This will cost in the neighborhood of $1.50 each in large quantities.

3. High-test hypochlorite (HTH) in tablet form should be substituted for the liquid Clorox disinfectant. The tablets will allow better control of the amount of disinfectant added to the water and will eliminate the present problem of liner corrosion because of accidental addition of too much Clorox.

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SUMMARY
OF
RESEARCH REPORT

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SUMMARY OF REPORT

The Office of Civil Defense provides basic supplies and equipment for stocking in public fallout shelters for use by occupants during a period of National emergency. The supplies furnished at present are: Food, Medical Kits, Water Containers, Sanitation Kits, and Radiological Monitoring Instruments.

The criteria adopted by OCD for the minimum amount of water which should be available in shelters from all sources is 3-1/2 gallons per shelter space stocked. To insure that this minimum amount is available, containers for storing water are supplied. These containers consist of 17-1/2 gallon metal drums with removable cover and double, 4-mil, polyethylene, "bag-type" liners. As of the end of fiscal 1966, approximately 10 million containers and liner sets were procured by OCD. Of these, approximately 8.25 million were already stocked in shelters, while 1.75 million were awaiting deployment.

The liners for these containers are made from flat polyethylene tubing by heat sealing. The inner liner has a spout feature at the top while the outer liner is a conventional open-mouth type bag.

Recent surveys of stocked fallout shelters by OCD have disclosed many instances of leaking and rusting water containers. These have been traced to one or more of the following causes:

1. Spillage of water between the outer liner and the inside of the drums because of careless handling during filling.

2. Seepage of water through the liner spout in the case of some of the liners in which the spout is knotted after filling.

3. Leakage through pinholes, cuts, punctures or defective heat-seals in the liners.

FOREWORD

This report was prepared by the General American Research Division of General American Transportation Corporation for the Stanford Research Institute under Subcontract No. 11609(6300A-200). It covers the research work performed between March 1967 and September 1967 on water container liners, which falls in the program area of OCD Work Unit 1433C.

The project was monitored by Mr. James F. Halsey of SRI's Civil Defense Technical Office.

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ABSTRACT

Recent surveys of stocked fallout shelters by the Office of Civil Defense have disclosed many instances of leaking and rusting water containers. These are due to one or more of the following causes:

1. Spillage of water between the outer liner and the inside of the drums because of careless handling during filling.

2. Seepage of water through the liner spout in the case of some of the liners in which the spout is knotted after filling.

3. Leakage through pinholes, cuts, punctures or defective heat-seals in the liners.

4. Leakage through cracks in the liners resulting from embrittlement because of chemical reaction with the sodium hypochlorite bleach (Clorox) used to disinfect the water.

The present research effort was directed primarily towards investigating new liner materials and new liner designs. The general conclusions that can be drawn from this are the following:

1. If cost considerations are paramount, the present double "bag-type" liner design should be retained, but the following grades of polyethylenes which have superior chemical resistance and heat-seal characteristics should be used:

   Ethyl Company - Visqueen L

   Union Carbide Corp. - Zendel HD

   A double liner using these new materials will cost about \$0.50 in production quantities.

2. For a liner significantly more reliable than the "bag-type", a blow molded, stackable design is recommended. This will cost in the neighborhood of \$1.50 each in large quantities.

3. High-test hypochlorite (HTH) in tablet form should be substituted for the liquid Clorox disinfectant. The tablets will allow better control of the amount of disinfectant added to the water and will eliminate the present problem of liner corrosion because of accidental addition of too much Clorox.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION 1

INTRODUCTION

The Office of Civil Defense provides basic supplies and equipment for stocking in public fallout shelters for use by occupants during a period of National emergency. The supplies furnished at present are: Food, Medical Kits, Water Containers, Sanitation Kits, and Radiological Monitoring Instruments.

The criteria adopted by OCD for the minimum amount of water which should be available in shelters from all sources is 3-1/2 gallons per shelter space stocked.[1] To insure that this minimum amount is available, containers for storing water are supplied. These containers consist of 17-1/2 gallon metal drums with removable cover and double, 4-mil, polyethylene, "bag-type" liners.[2] As of the end of fiscal 1966, approximately 10 million containers and liner sets were procured by OCD. Of these, approximately 8.25 million were already stocked in shelters, while 1.75 million were awaiting deployment.[3]

The liners for these containers are made from flat polyethylene tubing by heat sealing. The inner liner has a spout feature at the top while the outer liner is a conventional open-mouth type bag (Fig. 1).

The filling instructions require that after the inner liner is filled with water, one to two teaspoons of a liquid bleach such as Clorox* or equivalent be added as a disinfectant and the spout either heat-sealed or knotted.[4] The outer liner is then folded over the inner one or tied off and the cover replaced.

Experience with these containers over the past several years has shown

[1]Superscripts refer to References, p. 37.
*Sodium hypochlorite 5.25%, inert ingredients 94.75%.

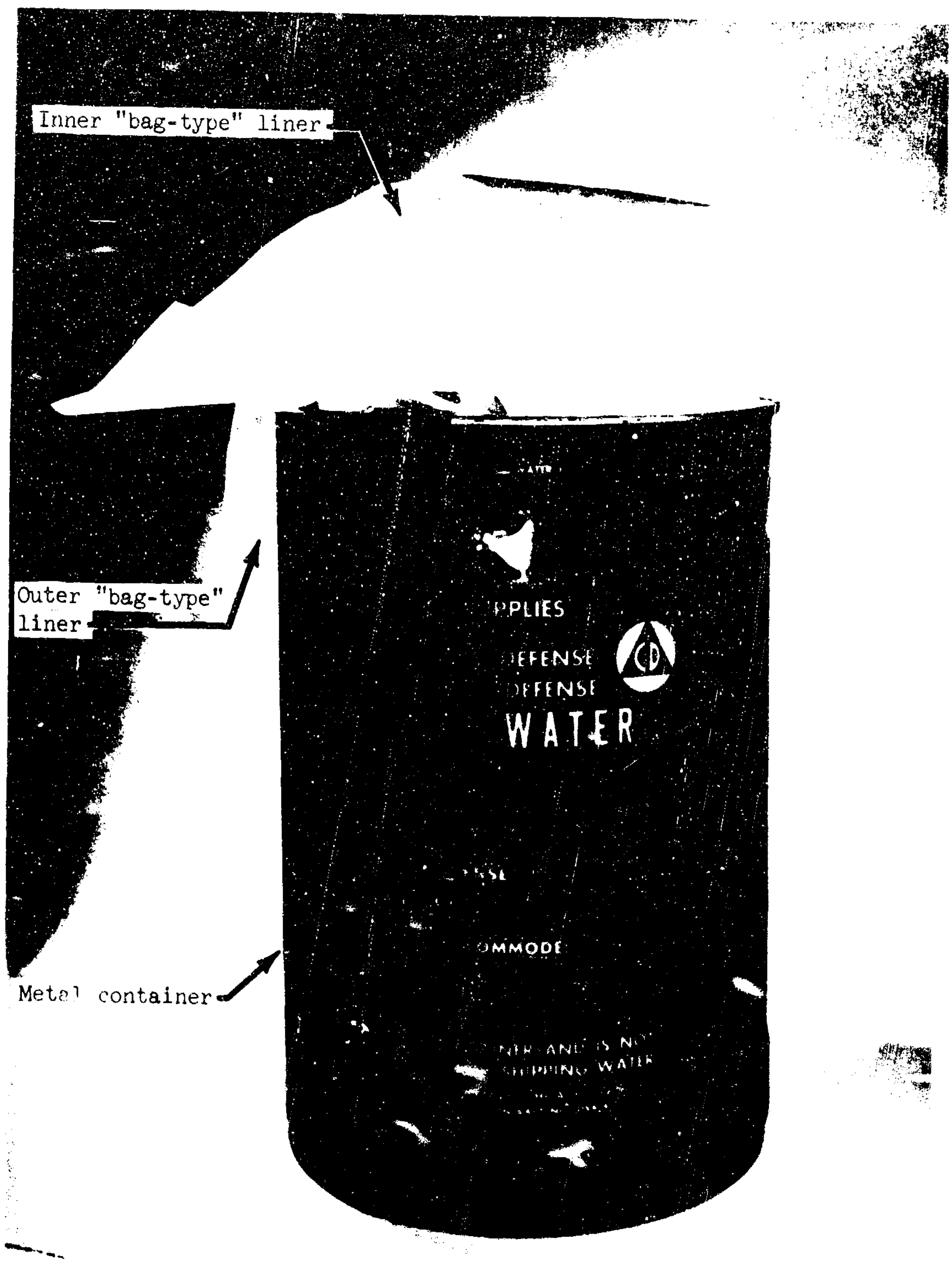

Figure 1 Civil Defense Water Container and Liners

that in many cases the water leaks out of the liners causing the drums to rust with eventual loss of the container. This is due to one or more of the following causes:

1. Spillage of water between the outer liner and the inside of the drums because of careless handling during filling.
2. Seepage of water through the spout in the case of some of those liners in which the spout is knotted after filling.
3. Leakage through pinholes, cuts, punctures or defective heat-seals in the liners.
4. Leakage through cracks in the liners resulting from embrittlement because of chemical reaction with the sodium hypochlorite in the bleach.

The present research was undertaken to overcome these problems. The effort was divided into three phases. The first phase was to identify plastic materials which were immune to attack by sodium hypochlorite and which had good heat-seal characteristics. The second phase was to investigate other designs which would eliminate the problems inherent in the "bag-type" liners. The third phase was to investigate methods for packaging sodium hypochlorite or other bleach to make it easy to add the specified amount to the water. This was considered necessary, since the rate of chemical reaction of bleach on polyethylene is proportional to the concentration of the bleach and any excess amount only accelerates deterioration of the liners.

A total of 15 materials from 1[illegible] manufacturers were evaluated. Of these, only two were found to be superior from both the chemical resistance and the mechanical strength standpoint. These materials are recommended for future liners.

Various liner designs were also investigated. Both collapsible and stackable types were considered. Of these, the blow molded stackable liner with a vacuum formed lid was judged superior to the present "bag-type" design.

The use of High Test Hypochlorite (HTH)* in tablet form is also recommended for disinfecting water. It is non-hygroscopic and the tablets can be made of such a size that only one would be necessary per container. This would avoid the guesswork involved in adding the liquid bleach to the water and eliminate the possibility of adding an excessive amount as is now the case.

*A dry stable form of calcium hypochlorite, $Ca(OCl)_2$, soluble in water with 70% available chlorine.

SECTION 2

EVALUATION OF MATERIALS FOR LINERS

2.1 Material Selection

A total of 15 plastic materials were evaluated for the liners. Fourteen of these were polyethylenes while one was a polypropylene (Table I). The materials were obtained from ten manufacturers who were requested to submit samples of only those materials which would meet the following requirements:

1. Food & Drug Administration approval for use in contact with potable water.
2. Immune to attack by Clorox bleach in the concentration of 2 teaspoons of Clorox per 17-1/2 gallons of water.
3. Good tensile strength.
4. Good strength of heat-seals.
5. Pinhole free when blow-molded or formed into film.
6. Low brittleness temperature.
7. Good aging characteristics, i.e., a life of at least 15 years.
8. Low cost.

The samples obtained were in film form with a nominal thickness in most cases of .004". Two tests were run. The first was an accelerated test in Clorox solution. The second was a test to determine the strength of heat-sealed seams.

2.2 Chemical Compatibility of Plastics with Sodium Hypochlorite

One to two teaspoons of household liquid bleach such as Clorox are required to be added to each 17-1/2 gallon water drum when they are filled. This is to prevent the growth of bacteria, fungi and algae.

TABLE I

PROPERTIES OF PLASTICS EVALUATED FOR LINER APPLICATION

Sample S/N	Manufacturer	Material*	Grade	Melt Index g/10	Density g/ml	Tensile Strength psi	Elongation %	Softening Point, Vicat °F	Brittleness Temperature °F	WVTR**
1	Allied Chemical Corp.	PE	GREX 2201	0.1	.938	3100	>800	260	--	0.6
2a	Dow Chemical Co.	PE	100E	0.45	.916	2250	550	194	<-94	--
2b	"	PE	510E	2.0	.919	2000	500	200	<-94	--
3	Eastman Chem. Products, Inc.	PE	810E	0.25	.918	2400	600	205	<-103	--
4	E. I. du Pont & Co.	E	Alathon 3445	0.5	.918	3300	550	--	--	1.0
5	Enjay Chemical Co.	Polypropylene	Escon 612	0.5	.902	4500+	19+	--	--	--
6	Ethyl Co.	PE	Visqueen L	<0.6	.916	2650	775	--	--	1.4
7	Phillips Petroleum Co.	PE	Marlex TR-101	0.2	.940	2100	500	23?	<-180	--
8a	Sinclair-Koppers Co.	PE	1000F	0.25	.918	2200	700	196	<-98	--
8b	"	PE	1010F	0.9	.917	2000	750	194	<-98	--
9	Union Carbide Corp.	PE	Zendel HD	--	--	2650	520	--	--	1.4
10a	U. S. Industrial Chem. Co.	PE	Petrothene NA 107	0.4	.917	2190	570	205	<-105	--
10b	"	PE	Petrothene NA 301	1.2	.917	2010	560	203	<-105	--
10c	"	PE	Petrothene NA 320	0.25	.919	2220	530	208	<-105	--

* PE: Polyethylene.

**WVTR: Water Vapor Transmission Rate, g/100 sq in./24 hrs/mil @ 100°F, 90% RH.

\+ At Yield Point.

The sodium hypochlorite (NaOCℓ) in the bleach however, is a strong oxidizing agent and attacks some polyethylenes, breaking up their long polyethylene chains and forming compounds having the organic radical CO. This results in the polyethylene becoming brittle and eventually disintegrating.

To identify the polyethylenes immune to such an attack, an accelerated test was undertaken on the samples furnished by the ten manufacturers.* This test is based on the rule-of-thumb that the rate of chemical reaction doubles with every 10°C rise in temperature.[5] Assuming the room temperature to be 28°C, a test conducted at 88°C for six weeks will then simulate a test conducted for 7.11 years at room temperature. This is derived as follows:

Test temperature	Equivalent weeks at 28°C for a 1-week test at the test temperature
28°C	1
38°C	2
48°C	4
58°C	8
68°C	16
78°C	32
88°C	64

Thus the equivalent weeks at 28°C for a test of 2, 4 and 6 weeks duration at temperature of 88°C are:

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* This test was similar to the one run at Fort Belvoir, Va., to find the reasons why liners were cracking.
Goldfein, S., et. al, "Civil Defense Water Containers", Report 12361, Materials Research Support Laboratory, USAERDL, Fort Belvoir, Va., November 1966.

2 x 64	=	128 weeks	=	2.46 years,
4 x 64	=	256 weeks	=	4.92 years, and
6 x 64	=	384 weeks	=	7.11 years, respectively.

In the test, samples of the 15 polyethylenes were kept in different solutions of Clorox and water at 88°C, and examined for possible attack after 2, 4, and 6 weeks. The solutions used were 0, 1/2, 1, 2, 3 and 4 teaspoons of Clorox in 17-1/2 gallons of water. The samples in the pure water were intended as controls while those in the 4 teaspoons solution were intended for determining the possible effects on the plastics of twice the maximum recommended concentration of Clorox.

A double beam infrared spectrophotometer was used to observe changes in the samples (Figure 2).* The carbonyl radical (CO) which is formed as a result of the chemical reaction between sodium hypochlorite and polyethylene gives a strong absorption band at 5.8 microns which can be easily detected by this instrument.

The curves of transmittance versus wavelength for one of the samples before the test and after the 6-week test in the 4 teaspoons solution are given in Figure 3**. From this it can be seen that the two spectra are practically identical and that no absorption band is present at 5.8 microns after the test. This means that the material would be chemically unaffected after 7.11 years in a solution twice as concentrated as the maximum recommended.

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* Model IR5, Range 2 to 15 microns, Beckman Instruments, Inc.

** Sample No. 6, Ethyl Co., Polyethylene Grade Visqueen L.

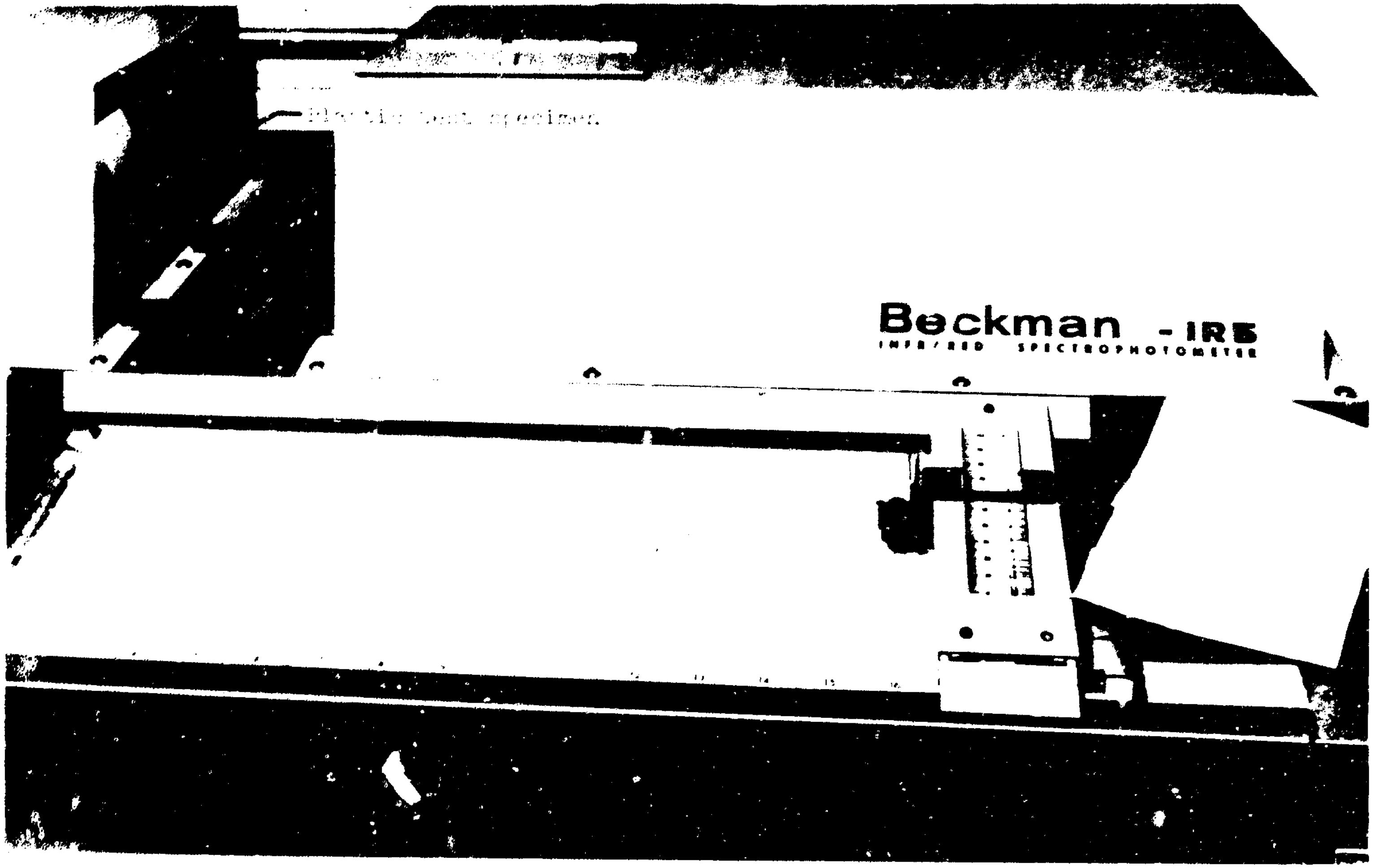

Figure [illegible] Infrared Spectrophotometer

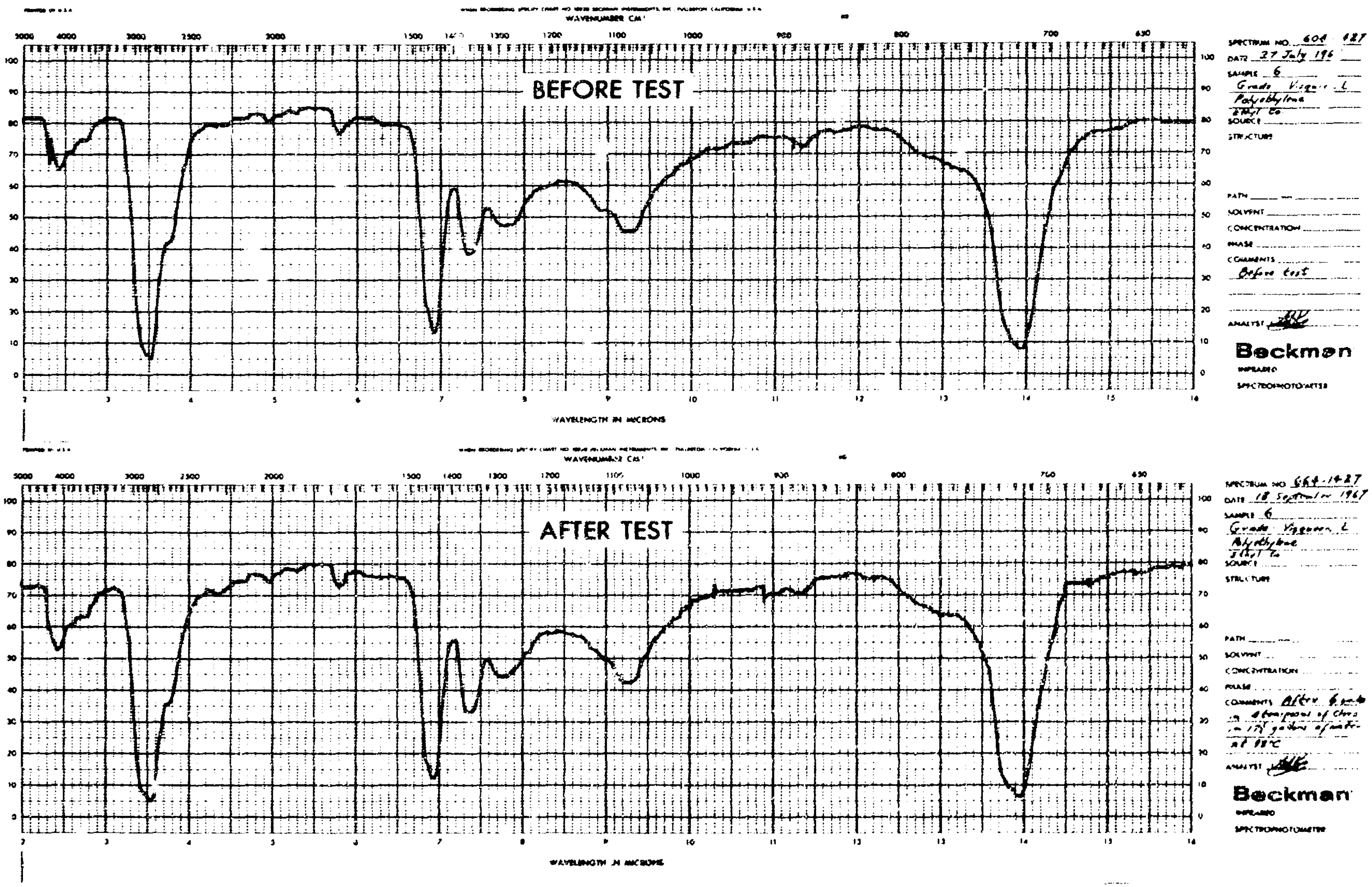

Figure 3 Spectra, Polyethylene, Before and After Chemical Compatibility Test

This degree of chemical resistance is judged to be more than adequate for the material to be recommended for liner application.

Of the 15 materials tested, 8 were found to be unaffected by sodium hypochlorite. From the chemical resistance standpoint any one of these eight would be suitable for liner use. The results of the tests are summarized in Table II.

2.3 Heat-Seal Characteristics of Plastics

The plastic samples were tested in accordance with federal test procedures to determine their heat-seal characteristics*. Twelve specimens of each grade were evaluated. Four of these were heat-sealed at 250°F, four at 300°F, and the remaining four at 350°F.

Each specimen consisted of two pieces of plastic, 5" x 3/4", heat-sealed 1/4" from one edge with a 1/16" seam. An impulse-type heat-sealer was used.

The tensile tests were performed on a Tinius Olsen tester (Figure 4). The initial grip separation was 2" and the rate of separation, 20 in./min. during the test.

2.3.1 Test Results

The results of the test are summarized in Table III. From this the following can be concluded:

1. The sealing temperature can be critical in determining the strength of a heat-seal. Hence the sealing temperature must be specified for each grade of material approved for fabricating a liner.

* Federal Specification L-P-378a Plastic Film (Polyethylene Thin Gage)
Federal Standard No. 406 Plastics: Methods of Testing.

TABLE II

CHEMICAL COMPATIBILITY OF PLASTICS WITH CLOROX+

Sample S/N	Manufacturer	Material*	Grade	Specimens after Test**		Recommendation for Use In Liners
				Appearance	Effect of Creasing***	
1	Allied Chemical Corp.	PE	GREX 2201	Hazy	Brittle	No
2a	Dow Chemical Co.	PE	100E	Clear	None	Yes
2b	"	PE	510E	Clear	None	Yes
3	Eastman Chem. Products, Inc.	PE	810E	Clear	None	Yes
4	E. I. du Pont & Co.	PE	Alathon 3445	Hazy	None	No
5	Enjay Chemical Co.	Polypropylene	Escon 612	Clear	Brittle	No
6	Ethyl Co.	PE	Visqueen L	Slightly hazy	None	Yes
7	Phillips Petroleum Co.	PE	Marlex TR-101	Hazy	Brittle	No
8a	Sinclair-Koppers Co.	PE	1000F	Clear	None	Yes
8b	"	PE	1010F	Clear	None	Yes
9	Union Carbide Corp.	PE	Zendel HD	Clear	None	Yes
10a	U. S. Industrial Chem. Co.	PE	Petrothene NA 107	Brownish stains	None	No
10b	"	PE	Petrothene NA 301	Clear	None	Yes
11	OCD Liner	PE	Unknown	Clear	Slightly brittle	No

+Clorox: Sodium hypochlorite 5.25%, inert ingredient 94.75%.

* PE: Polyethylene.

**After 6 weeks @ 88°C in 4 teaspoons of Clorox/ 17-1/2 gallons of water.

***Brittle: Material cracks when creased. None: Material does not crack when creased.

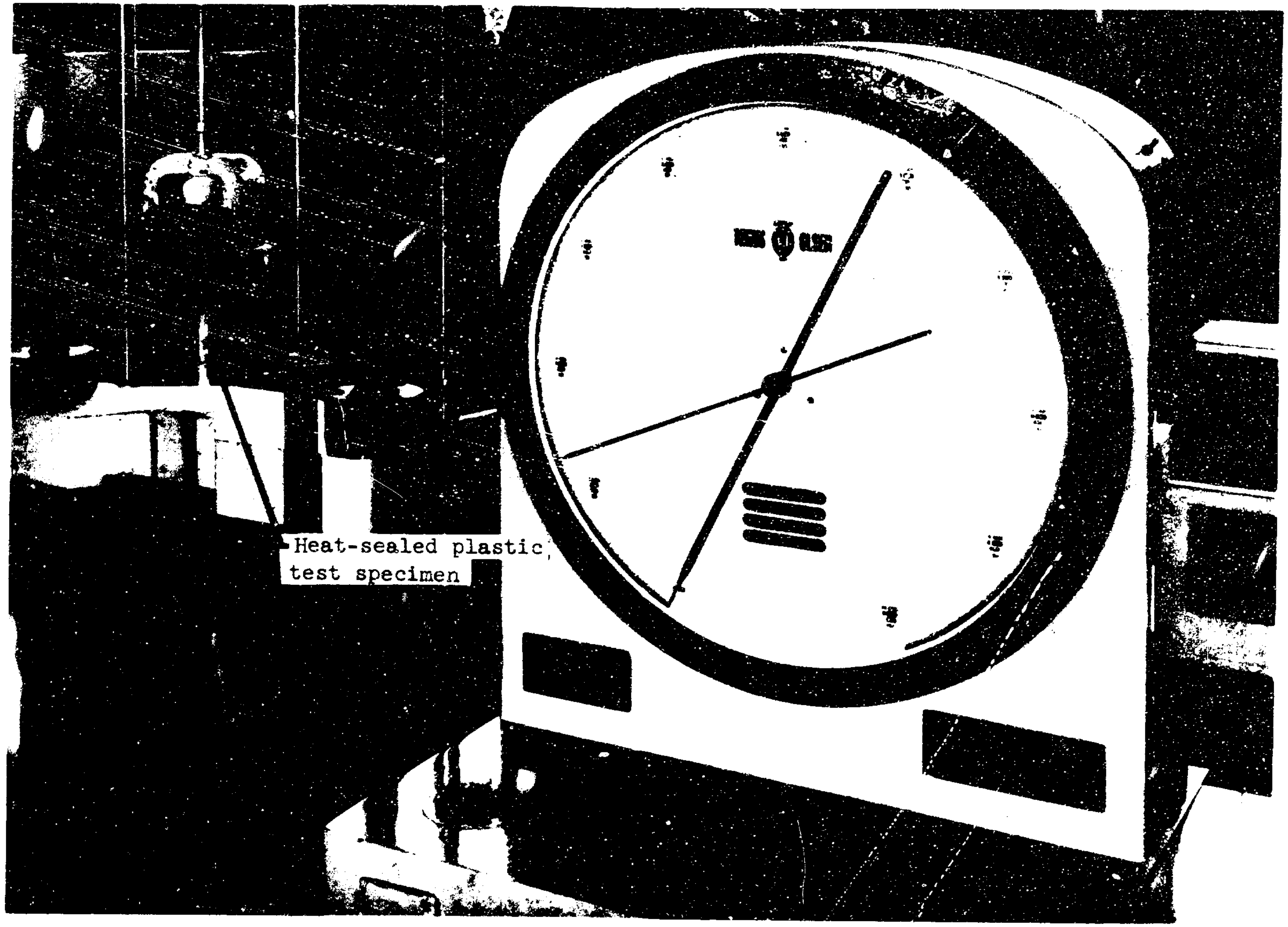

Figure 4 Setup for Tensile Testing of Heat-Seals of Plastics

TABLE III

HEAT-SEAL CHARACTERISTICS OF PLASTICS

S/N	Manufacturer	Material*	Grade	Test Specimen Thickness (in.)	Heat-Seal Breaking Load, lbs.**			Average Elongation + %	Material Breaking Load	
					Sealed at 250°F	Sealed at 300°F	Sealed at 350°F		(lbs.)	(psi)++
1	Allied Chemical Corp.	PE	GREX 2201	.0035	1.4	1.5	7.9	100	8.8	3350
2a	Dow Chemical Co.	PE	100E	.005	2.2	4.6	5.3	250	6.0	1600
2b	"	PE	510E	.004	4.9	4.4	4.5	250	5.5	1830
3	Eastman Chem. Products, Inc.	PE	810E	.004	4.6	4.5	4.0	200	4.9	1630
4	E. I. du Pont & Co.	PE	Alathon 3445	.004	3.5	4.1	4.3	150	4.5	1500
5	Enjay Chemical Co.	Polypro-pylene	Escon 612	.004	9.7	10.3	9.8	100	10.3	3430
6	Ethyl Co.	PE	Visqueen J.	.004	12.7	10.8	10.0	400	12.9	4300
7	Phillips Petroleum Co.	PE	Marlex TR-101	.004	5.0	5.3	5.4	150	5.8	1930
8a	Sinclair-Koppers Co.	PE	1000F	.004	4.1	4.4	4.4	600	5.8	1930
8b	"	PE	1010F	.002	1.8	1.8	2.0	600	2.1	1400
9	Union Carbide Corp.	PE	Zendel HD	.005	13.4	12.5	11.2	250	13.4	3[illegible]0
10a	U. S. Industrial Chem. Co.	PE	Petrothene NA 107	.004	4.5	4.9	4.8	400	5.1	1700
10b	"	PE	Petrothene NA 301	.004	3.8	3.7	3.7	300	3.8	1270
11	OCD Liner	PE	Unknown	.004	2.9	4.7	4.0	100	5.2	1730

* PE: Polyethylene.

**For specimen 3/4" wide. Each breaking load is the average value of four tests.

+ Of heat-sealed specimens at break.

++Obtained by dividing breaking load by original area of cross-section of test specimen.

2. The strength of a good heat-seal approaches the strength of the film itself. Hence the tensile strength of a material is an important consideration in selecting a material.

3. The ability of a film to deform to any configuration without rupture is important since this occurs when a liner is placed inside a container and filled with water. This property is characterized by the elongation of the material under load prior to failure and must be considered when specifying a material.

2.3.2 Heat-Seal Tests per MIL-B-43068(DOD-CD)*

The present "bag-type" liners for the OCD water containers were procured under MIL-B-43068(DOD-CD).

Each grade of plastic was also tested for heat-seal strength according to section 4.4.1 of this specification. The test procedures here require that a 3-1/2 lb. load be applied to a 1" wide heat-sealed specimen and the specimen examined after 5 minutes for any peel back or slippage at the seam.

When tested in this manner all specimens passed the requirements, although as determined previously, the heat-seals varied from good to poor.

This shows that section 4.4.1 of the specification is valueless in distinguishing between relatively poor heat-seals and good heat-seals. This section should therefore be changed and a test on a tensile tester substituted in its place for evaluating the heat-seals.

* Bag-liners, Polyethylene: 4 Mil Double Bag (Civil Defense)

2.4 Conclusion

2.4.1 Material Recommendation

Based on the chemical compatibility tests with sodium hypochlorite and the heat-seal tests, the following materials are recommended, especially for "bag-type" liners:

Sample S/N		Polyethylene Grade
6	Ethyl Co.	Visqueen L
9	Union Carbide Corp.	Zendel HD

Both have good chemical resistance, high tensile strength and elongation, and form excellent heat-seals.*

For blow molded liners where heat-sealing is not critical, the following materials are additionally recommended:

Sample S/N		Polyethylene Grade
2a	Dow Chemical Co.	100E
3	Eastman Chem. Products, Inc.	810E
8a	Sinclair-Koppers Co.	1000F
10a	U.S.Industrial Chem. Co.	Petrothene NA 301

2.4.2 Present OCD Liner Material

Chemical compatibility tests on present OCD liner material show that it becomes embrittled when in contact with sodium hypochlorite. Tested samples, when creased, produced locally weak areas.

The heat-seal strengths ranged from average to poor and the material exhibited low tensile strength and low elongation.

*This does not imply that other manufacturers not mentioned herein could not supply material which would meet requirements and be satisfactory for the purpose.

SECTION 3

LINER DESIGN

3.1 Improving Reliability of "Bag-type" Liners

The reliability of the present double "bag-type" liners is quite poor, as experience has shown. It can, however, be significantly improved if the material out of which it is made is changed, the quality control during manufacturing improved and the filling instructions altered. The required changes are as follows:

Materials. Liner cracking and poor heat-seals are directly traceable to the use of poor materials in the liners. The use of chemically resistant grades of polyethylenes which form good heat-seals will eliminate this problem. Some suggested grades are given in section 2.4.1.

Quality Control. Failure of heat-sealed seams is also due to poor quality control during manufacturing. New procurement specifications should be issued which give in detail the optimum temperature ranges, time cycles and pressure ranges for heat-sealing each grade of polyethylene approved for making the liners. In addition, the quality assurance requirements for the heat-seals should be tightened.

Filling Instructions. The present instructions allow the spout of the inner liner to be either knotted or heat-sealed after filling. This should be changed to make heat-sealing mandatory. Water seepage through knotted spouts will thus be eliminated.

3.2 Alternative Liner Designs

New liner designs were investigated to find a design significantly more reliable than the "bag-type" Five such designs are described below.

An important consideration in these designs is the ability to collapse or stack them. This is important to save shipping and storage costs*. One of the designs is stackable, the other four are collapsible. All are intended to be blow molded out of low density polyethylene. The higher reliability of these designs stems from the fact that the nominal wall thickness is about .015" as compared to .004" for the "bag-type" liners, and the fact that no heat-seals are present.

3.2.1 Stackable Liner

This liner has two parts, an open-mouth blow molded container and a vacuum-formed lid (Figure 5). During storage and shipping, the two parts are packed separately to reduce volume to a minimum. The sides of the container are slightly tapered to allow stacking.

In this design, the seal between the container top and the lid must be tight to prevent contamination or evaporation of the water. Six possible closure configurations are shown in Figure 6. Of these #6 appears most promising. This design is easy to mold and will allow a good seal even with fairly wide manufacturing tolerances for the two parts. In addition, dead space between the liner and the container will be kept to a minimum and a high degree of part stacking will be achieved.

Preliminary estimates show that the complete unit could be manufactured for less than $1.50 in large quantities. Production tooling would cost as follows:

---

* The cost for packaging and shipping a 16 gallon noncollapsible drum liner, made by the Plastics Division of GATX in 1965, was 25.2% of the cost of the drum liner, for a distance of 75 miles. An economical packing was used and the shipment was in truck load quantities.

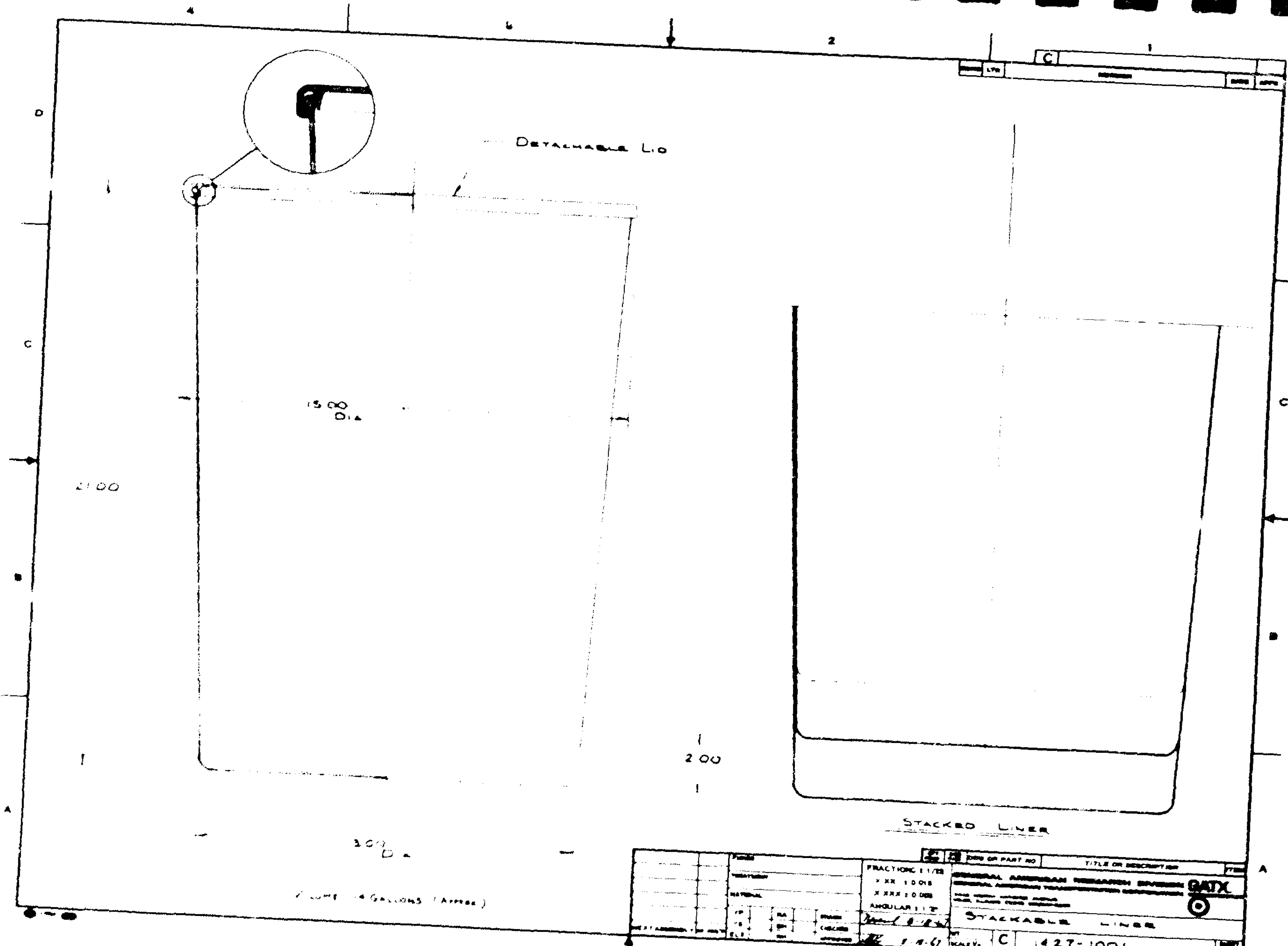

Figure [illegible] Stackable Liner

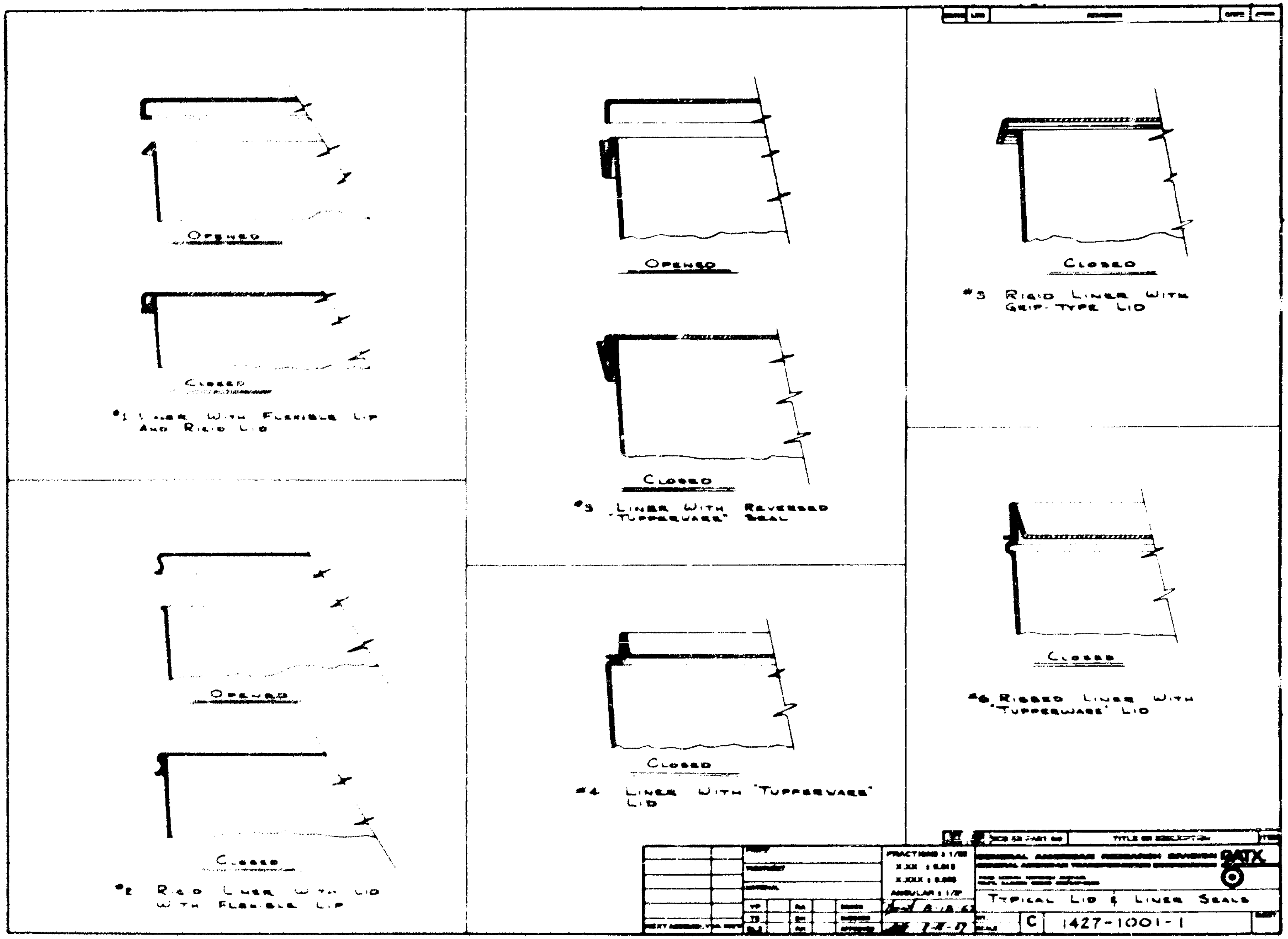

Figure [illegible] Typical Lid and Liner Seals

Blow mold, container, 17-1/2 gallons:	$ 6,500
Vacuum mold, lid:	3,000
Trimming tool, container:	4,500
Cutting die, lid:	1,500
Total	$15,500

The tooling should be sufficient for producing upwards of one million units.

3.2.2 Pleated Collapsible Liner

This liner is blow molded in one piece and is provided with circumferential pleats to allow it to be collapsed in the axial direction (Figure 7). It is provided with a threaded closure at the top for filling and emptying.

3.2.3 Ribbed Collapsible Liner

This is similar to the above liner except for the pleats which are different (Figure 8).

3.2.4 "Bell-O-Fram" Type Collapsible Liner

The sides of this liner are tapered towards the top (Figure 9). It can be axially collapsed by folding the side walls.

3.2.5 Foldable Liner

This liner is designed to be collapsed by compressing the sides. The ends are then folded over (Figure 10).

3.2.6 Recommended Blow Molded Liner

Of the five designs considered, the stackable liner is the most desirable one. It has several advantages over the collapsible ones. These advantages are:

1. The design is easy to manufacture.
2. The liner walls are not subject to bending or twisting

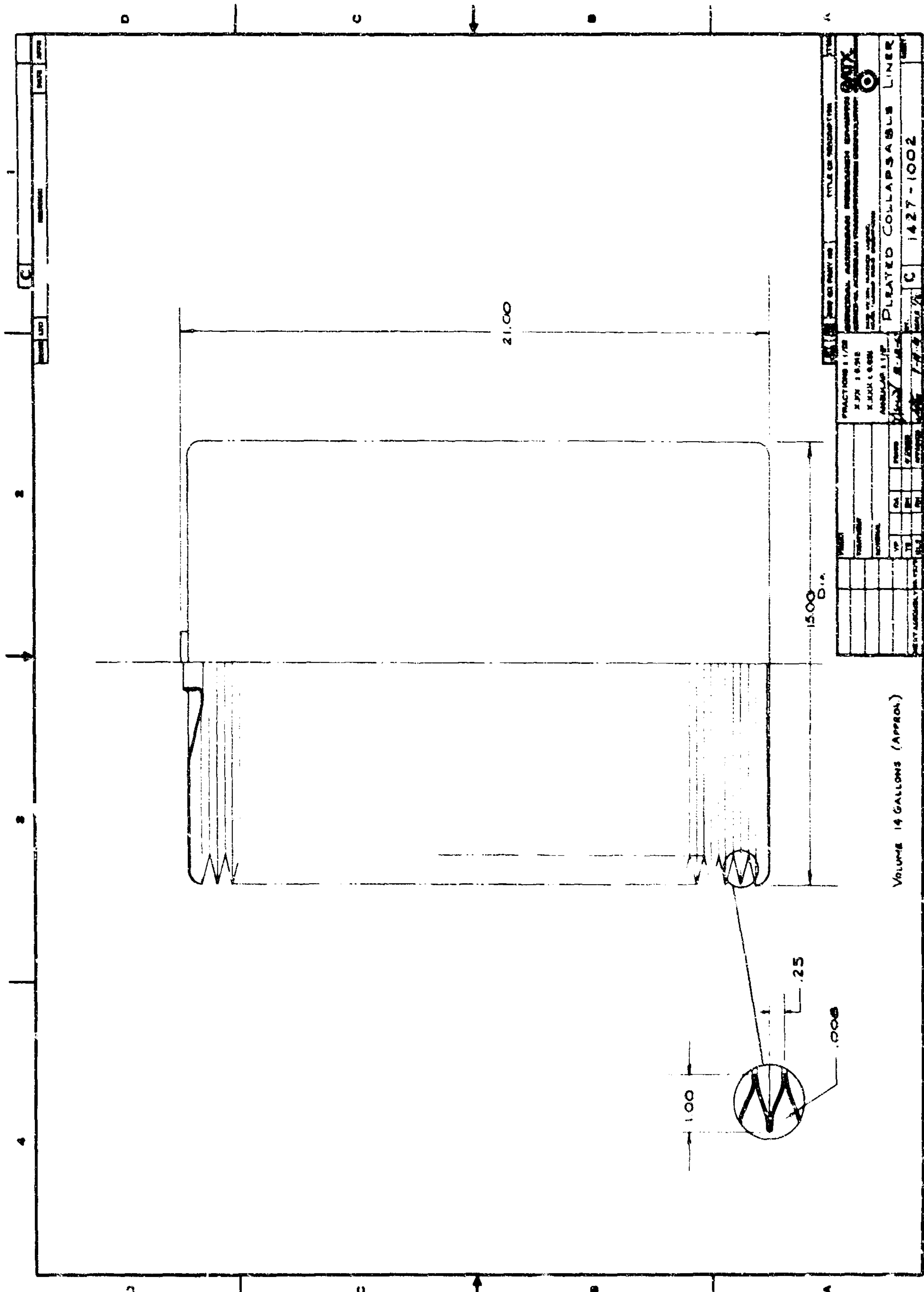

Figure 7 Pleated Collapsible Liner

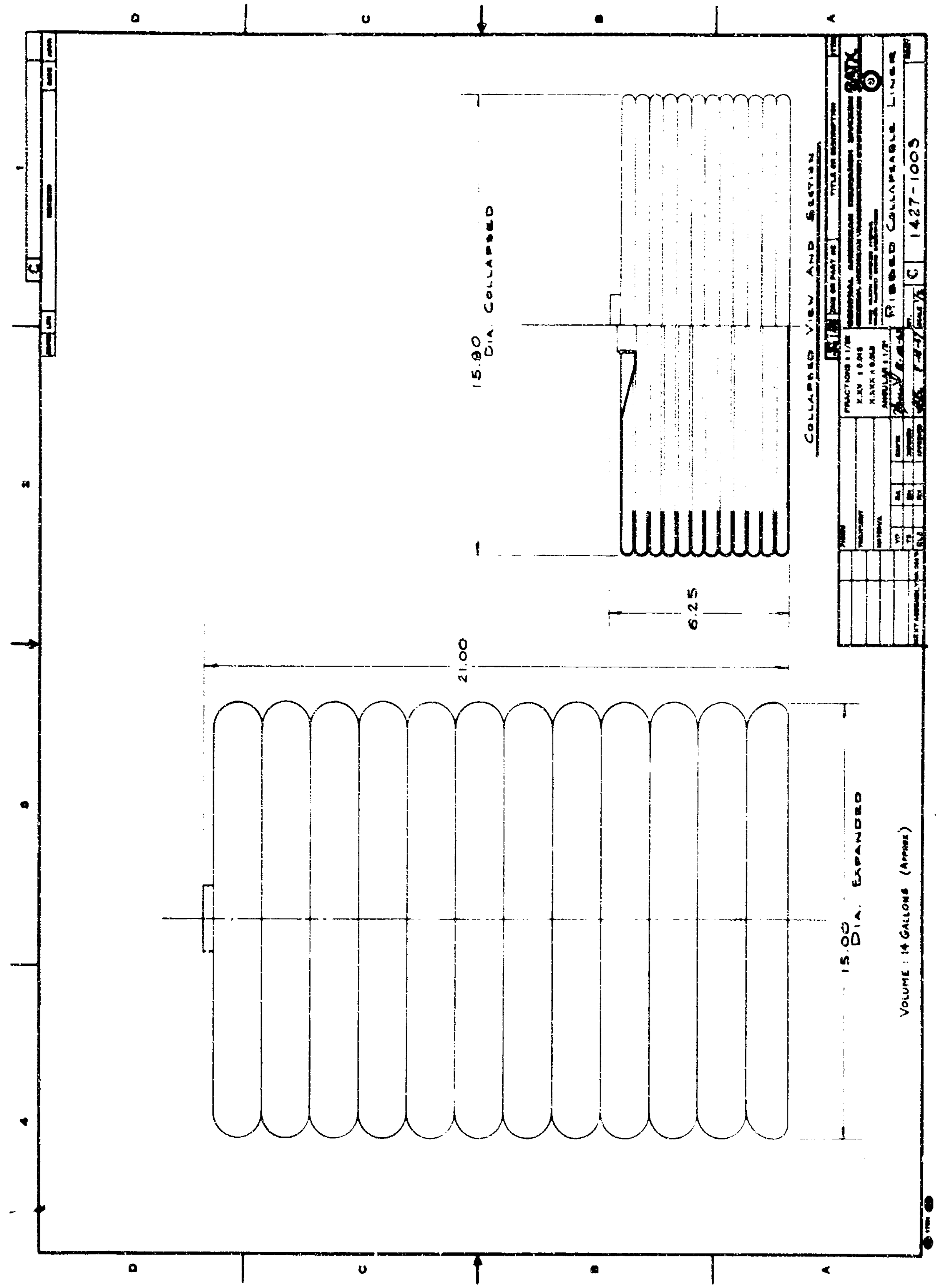

Figure 8 Ribbed Collapsible Liner

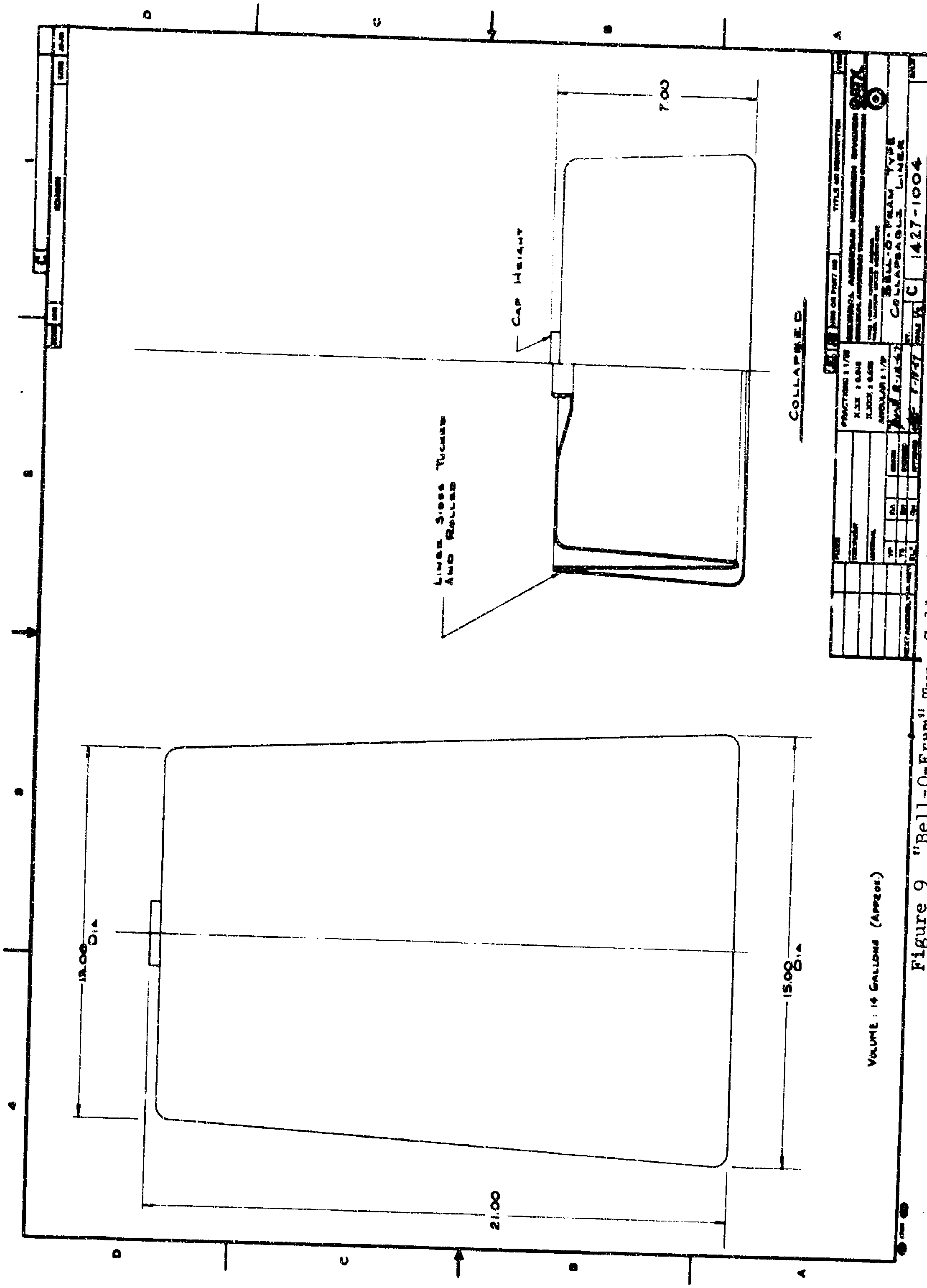

Figure 9 "Bell-O-Fram" Type Collapsible Container

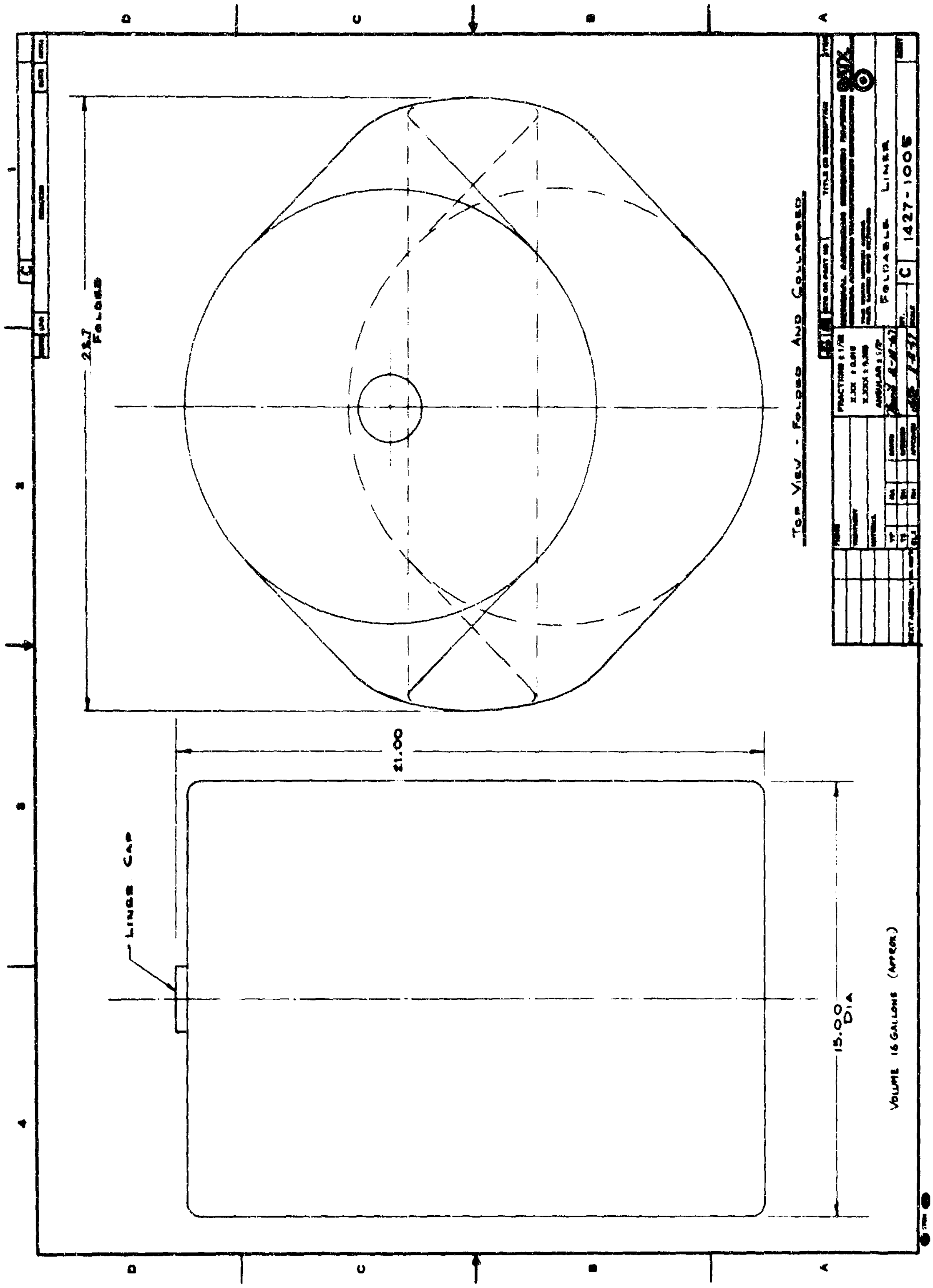

Figure 10 Foldable Liner

during storage and shipping. This eliminates the possibility of high local stresses and consequent danger of cracking of the liner.

3. No cutting of liners is necessary to convert empty containers into commodes. Also, resealing of liners for disposing used containers will be easy.

SECTION 4

DISINFECTANTS

Clorox bleach is at present recommended for disinfecting water stored in fallout shelters. Since an excess amount of it causes liners to deteriorate, other disinfectants were investigated to find one which was less harmful to the liners. Among the disinfectants investigated were halogens and halogen compounds such as chlorine, iodine, and calcium hypochlorite; and oxidizing agents such as potassium permanganate. Regenerative mechanical-chemical disinfecting processes utilizing ozone, ultra-violet rays and colloidal silver were judged unsuitable for shelter use and were not considered, although they are used to some degree in industrial water treatment.

4.1 Chlorine

Chlorine is the most common disinfectant used by municipal utilities or water works. It is a very effective bactericidal agent and has the advantage of low cost when processing large volumes of water. Gaseous chlorine, however, is highly dangerous and requires very rigid safety precautions when handling it. For this reason, it is not suitable for fallout shelter use.

Since chlorine is the principal disinfectant used in the practice of water treatment, the amount of any chemical disinfectant required to purify water is sometimes referred to in terms of chlorine content, i.e., a comparable amount of chlorine. When chlorine is added to water, a part of it reacts with chemicals and impurities including bacteria, and a part remains as free chlorine. The free chlorine is called residual chlorine while the chlorine which has reacted is referred to as the chlorine demand. Residual chlorine gradually disappears from the water by loss to the atmosphere, reaction to sunlight, metals, and other

bacteria. The common practice in municipal and private utilities is to chlorinate the water so that a residual chlorine content of 0.2 parts per million is maintained after a 5 minute contact period and 0.1 ppm after a 30 minute contact period. Tap water has a very low residual chlorine content, if any, due to the losses in the supply mains. Residual disinfectant should therefore be replaced in tap water if the water is to be stored for periods of up to two or three years.

4.2 Iodine

Unlike other halogens such as chlorine which combine with the protoplasm of the bacteria cell to destroy it, iodine inhibits the enzymes essential to bacteria metabolism causing them to die of "old age". Since iodine has a low chemical reactivity, it is a more effective disinfectant than chlorine since it can exert its full effect on destroying bacterial cells instead of combining with other chemicals. Also, it has no effect on polyethylene. The possibility of producing tastes and odors by combining with organic and other oxidizable materials is also minimized. Iodine requires lower demands than chlorine and the lower residuals are more stable and persist longer. It is approved by many states for disinfecting public drinking waters and swimming pools. Presently, it is used by the Army to disinfect canteen water in the field. Its shelf life is approximately 24 months. The major disadvantage with it is its high cost; in bulk quantities the cost is approximately $1.20/lb. in contrast to $0.12/lb. for chlorine gas

Iodine is well suited for a shelter application where inexperienced personnel must administer it to stored water containers. The basic chemical comes in a powdered form which can be easily bagged in small packets or made into tablets. When diluted in water, it is colorless, tasteless, and odorless up to two ppm concentrations. Higher concentrations may produce a taste which is not generally objectionable.

4.3 Hypochlorites

Hypochlorites are available in either powder or liquid form and are primarily used as bleach solutions for the pulp, paper, and textile industries. These liquid bleach solutions consist of sodium hypochlorite ($NaOC\ell$) or calcium hypochlorite ($Ca(OC\ell)_2$) in concentrations of up to 200 grams per liter (20% by weight). Calcium hypochlorite, which is nonhygroscopic, is however, the only hypochlorite found in powder form. Hypochlorite solutions are used as sterilizing agents and disinfectants and have proven to be very effective. This is attributed to the fact that hypochlorites when diluted in water provide both chlorine and oxygen, thereby serving as chlorinating and oxidizing agents; hence, one atom of chlorine combined in the hypochlorite molecule has the same effective power as two atoms of uncombined chlorine. Bleach solutions of hypochlorites are somewhat unstable, stability being dependent on: (1) hypochlorite concentration, (2) concentration of certain catalysts such as copper, nickel, or cobalt, (3) alkalinity or pH value of the solution, (4) temperature of the solution, and (5) exposure to light.

The present method of disinfecting stored water in fallout shelters is to administer one to two teaspoons of a 5.25% sodium hypochlorite bleach solution to each 17.5 gallon water container. One teaspoon of this solution provides a residual chlorine content of 0.2 ppm which is the standard residual maintained by most municipal utilities (see section 4.1). The dispensing of a liquid disinfectant is a problem which could be alleviated by the use of calcium hypochlorite in powdered form. Calcium hypochlorite is available in two grades: (1) high test hypochlorite (HTH), and (2) low test hypochlorite, with the high test having about 70% available chlorine and the low test about 35% available chlorine. In order to produce the same residual of 0.2 ppm in 17.5 gallons of water, approximately 20 milligrams of the HTH would be required. This quantity could be combined with a quick dissolving inert ingredient to give a tablet weighing about 500 to 600 milligrams -- approximately the size of an aspirin tablet. Such a tablet would be easy to handle and would dissolve and distribute the HTH quickly in the water and prevent high local HTH concentration which may be harmful to the plastic liner. Larger tablets of pure HTH are presently available for disinfecting swimming pools.

4.4 Potassium Permanganate

Potassium permanganate is a powerful oxidizing agent and is an excellent disinfectant for natural waters having a pH of less than 7.4. It is available in crystal form and is used primarily in the pretreatment of water to remove tastes and odors. The disadvantages of using potassium permanganate limit its value as a disinfectant for shelter use. These disadvantages are: (1) it is not normally used for post-treatment disinfection because the pH of treated water is usually above 7.4 where potassium permanganate is not too effective, (2) residual permanganate colors the water with a brown stain, and (3) it produces a fire or explosion hazard if brought in contact with a readily oxidizable material.

4.5 Halazone

Halazone is a commercial name for sulfondichloraminobenzoic acid and is available in tablet form as an emergency method for disinfecting water. The basic compound is a white powder which is somewhat unstable, particularly when exposed to light, hence environmental conditions can limit its storage life. It is used as a water disinfectant by the Army with excellent results; however, it can produce a disagreeable taste.

4.6 Comparison of Disinfectants

Table IV lists the types of disinfectants with their costs in the decreasing order of preference. Although the present method of disinfecting stored water in shelters has the advantages of low cost and easy availability of the disinfectant, the inability of the personnel to dispense the correct amount indicates that a better handling technique must be used. For this reason, high test hypochlorite (HTH) in tablet form is recommended as the best disinfectant for shelter use. All the disinfectants, with the exception of the bleach solution (Clorox) presently used, will require an additional logistics problem; i.e., the manufacture, supply, and storage of the disinfectant. This disadvantage, however, is acceptable when considering the possibility of total loss of the present liners and containers.

TABLE IV

DISINFECTANTS

Disinfectants	Cost per Pound* ($)	Disinfectant Cost per 17.5 gallons of water+($)	Advantages and Disadvantages
High Test Hypochlorite (HTH) (70% available Chlorine)	.30	.0000132	Easily packaged, low cost
Iodine	1.20	.0000343	Easily packaged, high cost
Halazone	8.00	.00087	Easily packaged, very high cost
Clorox (5.25% Sodium Hypochlorite)	.03	.0000165	Widely available, no logistics, difficult to dispense

*Based on bulk costs.

+Excluding packaging costs, based on 0.2 ppm residual chlorine.

NOTE: Disinfectants and sterilizing processes such as chlorine, chloramine, hypochlorous acid, ozone, ultra-violet rays, and colloidal silver were investigated, but are not reported, since they were considered unsuitable for the application.

SECTION 5

ENCAPSULATION OF DISINFECTANTS

By encapsulating or packaging the correct amount of disinfectant for each water container, it is possible to eliminate the overdosage problem which occurs now in the filling operation at the shelter level. Several packaging techniques are available depending on the chemical reactivity of the disinfectant and on its form, i.e., whether it is a solid or a liquid.

5.1 Solid Disinfectant

For solid disinfectants such as high test hypochlorite (HTH) and iodine, the following packaging methods are available:

1. Gelatine capsules. These are of the two-piece type with capacity ranging from 1.5 grains to 1 ounce.
2. Pouches. These are made from 1 to 3-mil film of water soluble polyvinyl alcohol, methyl cellulose, polyethylene oxide or starch.
3. Tablets.

Tablets are the least expensive of the three methods. Preliminary cost estimate for HTH tablets in small quantities is $1.00/200 tablets. This amount will be sufficient to disinfect 200 containers, i.e., enough water for 1000 people. The cost per shelter space is thus $.001.

Another advantage with the tablets is that they do not leave a film or slime on the water surface like the gelatine capsules or some of the pouch materials. This is desirable since a slimy film on the water surface may be psychologically disagreeable to the shelterees.

5.2 Liquid Disinfectants

F liquid disinfectants such as sodium hypochlorite bleach solution, the following packaging methods are available:

1. Gelatine capsules. These are usually of soft gelatine of the one-piece type and range in capacity from one drop of liquid to 1 ounce.
2. Glass and plastic vials.

Liquids are generally more difficult to package than solids. Also, their packaging cost is significantly more compared to the cost of forming tablets from powders. Of the two forms of disinfectants therefore, solid disinfectants are to be preferred.

SECTION 6

SUMMARY

To solve the problem of liner failures in the present OCD water containers and prevent water leakage and rusting of the drums, the following is recommended:

1. If costs have to be kept to a minimum, the present "bag-type" liner design should be retained but its reliability upgraded by taking the following steps:

   a. Specify only materials with superior chemical resistance and heat-sealing characteristics. Two such polyethylene grades are:

      Ethyl Company - Visqueen L
      Union Carbide Corp. - Zendel HD

   b. Improve quality of heat-seals by specifying in detail the optimum temperature ranges, time cycles and pressure ranges for heat-sealing for each recommended grade of polyethylene.

   c. Upgrade quality control and quality assurance requirements during manufacture.

   d. Change filling instructions to make heat-sealing of the inner liner spout mandatory after filling the liners with water.

2. For a liner significantly more reliable than the "bag-type", a blow molded, stackable design with a vacuum-formed lid should be used (section 3.2.1). The unit cost for this will be about $1.50 in large quantities. Production tooling will cost about $15,000 and should be sufficient for producing upwards of one million units.

3. Substitute high test hypochlorite (HTH) for the Clorox as a disinfectant for the stored water. In tablet form (one to a container), HTH will cost less than $.001/shelter space.

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General American Transportation Corporation, Niles, Ill.

WATER CONTAINER LINER
OCD Work Unit 1433C
Interim Report 1427 (UNCLASSIFIED)
By R. B. Neveril, A. L. Kapil
September 1967, pp. 50

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CONTAINERS, FALLOUT SHELTERS, PLASTICS, WASTES (SANITARY ENGINEERING), WATER, WATER SUPPLIES

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